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Overweight and obesity in relation to cardiovascular disease risk factors among medical students in Crete, Greece

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Abstract

Background: Recent data indicate increasing rates of adult obesity and mortality from cardiovascular disease (CVD) in Greece. No data, however, are available on prevalence of overweight and obesity in relation to CVD risk factors among young adults in Greece.

Methods: A total of 989 third-year medical students (527 men, 462 women), aged 22 ± 2 years, were recruited from the University of Crete during the period 1989–2001. Anthropometric measures and blood chemistries were obtained. The relationships between obesity indices (body mass index [BMI], waist circumference [WC], waist-to-hip ratio [WHpR], waist-to-height ratio [WHtR]) and CVD risk factor variables (blood pressure, glucose, serum lipoproteins) were investigated.

Results: Approximately 40% of men and 23% of women had BMI ≥ 25.0 kg/m^2. Central obesity was found in 33.4% (average percentage corresponding to WC ≥ 90 cm, WHpR ≥ 0.9 and WHtR ≥ 50.0) of male and 21.7% (using WC ≥ 80 cm, WHpR ≥ 0.8, WHtR ≥ 50.0) of female students. Subjects above the obesity indices cut-offs had significantly higher values of CVD risk factor variables. BMI was the strongest predictor of hypertension. WHtR in men and WC in women were the most important indicators of dyslipidaemia.

Conclusion: A substantial proportion of Greek medical students were overweight or obese, obesity status being related to the presence of hypertension and dyslipidaemia. Simple anthropometric indices can be used to identify these CVD risk factors. Our results underscore the need to implement health promotion programmes and perform large-scale epidemiological studies within the general Greek young adult population.

Background

Overweight and obesity are recognized as an "escalating epidemic" affecting both developed and developing countries [1,2]. Obesity and its associated morbidities are leading causes of cardiovascular disease (CVD), type-2 diabetes, some types of cancer and several other health problems [3]. Recent data show that mortality from CVD is increasing in Greece, in contrast to trends observed in northern Europe and the USA [4,5]. Age-adjusted ischaemic heart disease mortality in men aged 45–74 years almost doubled from 1956 to 1978 and the prevalence of myocardial infarction per 100.000 adults aged 30–69 years increased from 230 in 1981 to 349 in 1988 [5]. This unfavourable trend is partially attributed to increased prevalence of obesity as indicated by existing literature [6,7]. Adult obesity levels in Greece are the second highest in Europe, exceeding 25% for men and 35% for women [8].

The childhood roots of adult obesity and also CVD are widely recognized and associated with calls for health promotion targeted at youth [9–11]. Recent studies have indicated the presence of increasing trends in overweight and obesity among children and adolescents in Greece [6,12], but there is complete lack of data regarding young adult groups. Moreover, although there are many studies on the health status of medical students, a target group of particular interest as they are future physicians, these have mostly tracked the use of alcohol and tobacco [13,14]. The occurrence of obesity and other risk factors for coronary heart disease has not been extensively examined, particularly among European medical students.

The aim of this descriptive study was to assess the prevalence of overweight, obesity and other CVD risk factors, namely high blood pressure and dyslipidaemia, among University of Crete medical students. We investigated the relationships of four different obesity indices (body mass index, waist circumference, waist-to-hip ratio, waist-to-height ratio) with blood pressure, glucose, serum lipids and lipoproteins. Finally, we examined which of these indices could better predict the presence of such risk factors in this young adult group.

Methods

Subjects

The survey was carried out within the training framework of the Clinical Nutrition class, which is presented in the third year of the medical course in the University of Crete School of Medicine [15]. Between the years 1989–2001, all students registered in the third year of their studies (21–49 men and 17–47 women per year) were invited to participate in the study and sign appropriate consent forms. The average annual participation rate was 98.2% (range 95.3–100%). Eighteen students were excluded from the analyses because of missing data on potential confounding variables. The final sample included 989 students (527 males, 462 females), aged 20–40 years (mean age 22, standard deviation [SD] 2) with complete measurements for all variables other than glucose. Blood glucose was available for a sub-sample of 727 students (412 men, 346 women).

Questionnaires

Purpose designed questionnaires were administered to ascertain biographical data, lifestyle behaviours on topics including cigarette smoking and alcohol consumption, and medical and family history of cardiovascular diseases. In order to validate the results multiple crosschecked questions on the same topic were addressed to the participants. Smokers were classified as those who stated smoking more than one cigarette per day for at least three consecutive months. Ex-smokers were defined as those who had not been smoking for the last three consecutive months, and non-smokers as those who did not fall in any of the two previous groups. The questionnaires remained unchanged over the years.

Physical characteristics

A digital scale (Seca) was used to measure body weight (BW) with an accuracy of ± 100 g. Subjects were weighed without shoes, in their underwear. Standing body height (BH) was measured without shoes to the nearest 0.5 cm with the use of a commercial stadiometer with the shoulders in relaxed position and arms hanging freely. Body mass index (BMI) was calculated as BH in kilograms (kg) divided by the square of the BH in meters (m^2). Waist circumference (WC) was measured in the middle between 12^{th} rib and iliac crest at the level of umbilicus and the hips circumference (HC) at the fullest point around the buttocks. WC (cm) was divided by HC (cm) and BH (m) in order to calculate the waist-to-hip (WHpR) and waist-to-height (WHtR) ratio respectively. Means of replicates were used in all anthropometric measurements, which were carried out by the same faculty members over the years.

In order to measure blood pressure, subjects were seated in a chair with their back supported and their arms bared and supported at heart level. Measurement was performed with the student not having ingested coffee or smoked for 30 minutes and after at least five minutes of rest. The appropriate cuff size was used to ensure an accurate measurement. Measurements were taken using a mercury sphygmomanometer applied on the right arm of the participants. First and fifth Korotkoff sounds were recorded for systolic and diastolic readings respectively. Two readings separated by two minutes were averaged. If they differed by more than 5 mmHg, one additional reading was obtained and then averaged.

Biochemical analyses

Early morning ,venous blood samples were drawn for biochemical screening tests, following a 12-hour overnight fast. The blood samples were transferred to the Nutritional Research Laboratory of the University of Crete in tanks containing ice packs so as to maintain a temperature of 3–4°C. Blood was centrifuged and 1.5 mL aliquots were pipetted into plastic Eppendorf tubes. One aliquot was used for blood analysis of triglycerides (TG), total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) measurements on the same day of collection, while the other was stored (at -80°C). TG was determined using Fossati's method [16]. TC was determined by Allain's method [17]. HDL-C was measured by the heparin-manganese precipitation method [18] while low-density lipoprotein cholesterol (LDL-C) was calculated as follows: LDL-C = TC - (HDL-C + TG/5) [19]. The ratio of TC to HDL-C (TC:HDL-C) was calculated. Coefficients of variation for measurement error during 1989–2001 ranged between 4.3 and 12.4% for TC and HDL-C. Blood glucose (BG) levels were measured by the exokinase method, using an auto-analyser AU-640 (Olympus Instruments).

Assignment of CVD risk factors

Based on the International Obesity Task Force [20], convened by the World Health Organization, a subject with BMI of 25.0 to 29.9 kg/m^2 was defined as overweight; a BMI ≥ 30.0 kg/m^2 was defined as obese. The WC, WHpR and WHtR measurements were used to determine the extent of central adiposity. For WC, cut-off points of ≥ 90 cm in men and ≥ 80 cm in women were used [21]. A WHpR ≥ 0.9 in men and ≥ 0.8 in women was considered to represent central obesity [21], and WHtR values of ≥ 50.0 in either sex were adopted as cut-offs [22].

Participants were classified as having elevated blood pressure if they reported taking anti-hypertensive medication or had a systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg. High-normal blood pressure was defined as blood pressure ≥ 130/85 – < 140/90 mmHg. The cut points correspond to the Sixth Joint National Committee on High Blood Pressure criteria for high blood pressure [23].

Dyslipidaemia was defined as TC ≥ 5.2 mmol/l (200 mg/dl), TG ≥ 1.5 mmol/l (150 mg/dl), LDL-C ≥ 3.4 mmol/l (130 mg/dl), and HDL-C < 0.9 mmol/l (40 mg/dl). These cut-offs correspond to the Adult Panel Treatment III criteria for borderline high TC, TG, LDL-C and low HDL-C levels [24]. A TC:HDL-C ≥ 4 was also considered a adverse serum lipid profile [25].

Impaired fasting glucose was defined as BG ≥ 6.1 mmol/l (110 mg/dl) based on the Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus [26].

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (version 8.0, SPSS, Inc) software. Analysis of covariance (ANCOVA) was used to examine for differences in the lipidaemic profiles of men and women, adjusting for the year of examination. The chi-square (χ^2) test (or Fisher's exact test for 2 × 2 data tables) was used for categorical data. Although the set of data was collected over a 13-year-period, we did not examine for time trends since the cross-sectional design of the survey and the small number of participants per year would preclude any definite conclusions. However, in order to account for any possible time effects, the year of examination was included in all statistical analyses as an independent variable.

The relationship between obesity and other CVD risk factor variables was first examined with univariate analyses using obesity indices as categorical variables. Average differences in blood pressure, glucose, serum lipids and lipoproteins were calculated using ANCOVA with covariates age, sex, tobacco use and year of examination. Stepwise linear regression techniques were applied to assess the extent to which CVD risk factors depend on the obesity indices considered using the same independent variables. Logistic regression models were applied to calculate odds ratios (OR) for the presence of CVD risk factors after adjustment for age, tobacco use, and year of examination. A level of $p < 0.05$ was used to indicate statistical significance in all analyses.

Results

Prevalence of overweight, obesity, and other CVD risk factors

The fasting blood glucose levels and lipidaemic profiles of University of Crete medical students are given in Table 1. Men had significantly higher values of BG ($p < 0.001$), TG ($p < 0.001$), LDL-C ($p = 0.010$) and TC:HDL-C ($p < 0.001$), and lower values of HDL-C ($p < 0.001$) than their female counterparts. Table 2 presents the distribution of obesity indices, blood pressure, blood glucose, serum lipids and lipoproteins among medical students. The prevalence of overweight or obesity (BMI ≥ 25.0 kg/m^2) was 39.5% in male and 23.3% in female students. Central obesity levels were significantly higher in men than women, using the WC (32.6% vs. 21.9%, $p < 0.001$) or WHtR (37.6% vs. 12.8%, $p < 0.001$) cut-offs. Forty eight percent of men and 36.1% of women ($p < 0.001$, difference between the genders) had blood pressure levels ≥ 130/85 mmHg. A significantly higher percentage of males than females had high TG, LDL-C, TC:HDL-C, or low HDL-C ($p < 0.001$ for all analyses). Only 10 students (8 men, 2 women) had BG levels ≥ 6.1 mmol/l (110 mg/dl).

Relationships between obesity indices and other CVD risk factors

The relationships between blood pressure, glucose, serum lipids and lipoproteins, and obesity indices treated as categorical data are presented in Table 3. Across the four BMI categories, all CVD risk factor variables except BG demonstrated a significant increase. For WC and WHtR, subjects above the selected cut-off points had significantly higher values of SBP, DBP, TC, TG, LDL-C, TC:HDL-C and lower values of HDL-C. High WHpR values were also related to adverse serum lipid profile.

Table 1: Blood glucose and lipidaemic profiles of University of Crete medical students

	Men[1]	Women[2]	
	Mean ± S.D.[3]		p-value[4]
BG (mmol/l)	4.73 ± 0.59	4.59 ± 0.56	<0.001
TC (mmol/l)	4.65 ± 0.91	4.63 ± 0.87	NS[5]
TG (mmol/l)	0.83 ± 0.43	0.66 ± 0.28	<0.001
HDL-C (mmol/l)	1.19 ± 0.30	1.44 ± 0.35	<0.001
LDL-C (mmol/l)	3.01 ± 0.86	2.86 ± 0.82	0.010
TC:HDL-C	4.12 ± 1.30	3.40 ± 1.02	<0.001

[1] N = 527 except for BG analysis where N = 412. [2] N = 462 except for BG analysis where N = 346. [3] Standard deviation. [4] ANCOVA (adjusting for the year of examination) for differences between the two genders. [5] Not significant.

Table 2: Distribution of obesity indices, blood pressure, glucose, and lipoproteins among University of Crete medical students

	Men		Women		
	N	%	N	%	p-value[1]
BMI (kg/m^2)					
< 20.0	30	5.7	83	18.0	<0.001
20.1–24.9	289	54.8	271	58.7	
25.0–29.9	181	34.4	92	19.9	
≥ 30.0	27	5.1	16	3.4	
WC (cm)					
< 90 () – < 80 ()	355	67.4	361	78.1	<0.001
≥ 90 () – ≥ 80 ()	172	32.6	101	21.9	
WHpR (cm/cm)					
< 0.9 () – < 0.8 ()	369	70.0	321	69.5	NS[2]
≥ 0.9 () – ≥ 0.8 ()	158	30.0	141	30.5	
WHtR (cm/m)					
< 50.0	329	62.4	403	87.2	<0.001
≥ 50.0	198	37.6	59	12.8	
Blood pressure (mmHg)					
< 130/85	272	51.6	295	63.9	<0.001
≥ 130/85 – < 140/90	185	35.1	136	29.4	
≥ 140/90	70	13.3	31	6.7	
BG (mmol/l)					
< 6.1	404	98.1	344	99.4	NS
≥ 6.1	8	1.9	2	0.6	
TC (mmol/l)					
< 5.2	390	74.0	352	76.2	NS
5.2–6.1	109	20.6	90	19.5	
≥ 6.2	28	5.4	20	4.3	
TG (mmol/l)					
< 1.5	482	91.4	453	98.0	<0.001
≥ 1.5	45	8.6	9	2.0	
HDL-C (mmol/l)					
< 0.9	76	14.4	21	4.6	<0.001
≥ 0.9	451	85.6	441	95.4	
LDL-C (mmol/l)					
< 3.4	365	69.2	352	76.2	NS
3.4–4.0	111	21.1	79	17.1	
≥ 4.1	52	9.7	31	6.7	
TC:HDL-C					
< 4	298	56.5	370	80.1	<0.001
≥ 4	229	43.5	92	19.9	

[1] Chi-square test (Fisher's exact test where appropriate) for differences between the genders.[2] Not significant.

Table 3: Relationship between obesity indices and CVD risk factor variables in University of Crete medical students

Obesity index	N[1]	SBP (mmHg)	DBP (mmHg)	BG (mmol/l)	TC (mmol/l)	TG (mmol/l)	HDL-C (mmol/l)	LDL-C (mmol/l)	TC:HDL-C
		Mean ± S.E.[2]							
BMI (kg/m^2)									
< 20.0	113	112 ± 1.2	75 ± 1.0	4.50 ± 0.06	4.56 ± 0.09	0.70 ± 0.04	1.36 ± 0.04	2.83 ± 0.09	3.56 ± 0.13
20.0–24.9	560	117 ± 0.5	76 ± 0.4	4.63 ± 0.03	4.57 ± 0.04	0.71 ± 0.02	1.30 ± 0.02	2.87 ± 0.04	3.66 ± 0.05
25.0–29.9	273	121 ± 0.8	79 ± 0.6	4.67 ± 0.04	4.74 ± 0.06	0.80 ± 0.02	1.24 ± 0.02	3.08 ± 0.06	4.07 ± 0.08
≥ 30.0	43	123 ± 1.9	82 ± 1.5	4.77 ± 0.10	4.89 ± 0.15	1.06 ± 0.06	1.25 ± 0.06	3.05 ± 0.15	4.17 ± 0.21
p-value[3]		<0.001	<0.001	NS[4]	<0.001	<0.001	0.010	0.018	<0.001
WC (cm)									
< 90[5] – 80[6]	716	116 ± 0.6	76 ± 0.4	4.58 ± 0.03	4.56 ± 0.04	0.69 ± 0.02	1.36 ± 0.02	2.84 ± 0.04	3.54 ± 0.05
≥ 90 – 80	273	120 ± 0.9	79 ± 0.6	4.64 ± 0.04	4.74 ± 0.06	0.89 ± 0.03	1.19 ± 0.02	3.05 ± 0.06	4.13 ± 0.08
p-value[7]		<0.001	<0.001	NS	0.011	<0.001	<0.001	0.002	<0.001
WHpR (cm/cm)									
< 0.9[5] – 0.8[6]	690	117 ± 0.6	77 ± 0.4	4.59 ± 0.03	4.58 ± 0.04	0.69 ± 0.02	1.34 ± 0.02	2.88 ± 0.04	3.61 ± 0.06
≥ 0.9 – 0.8	299	119 ± 0.9	78 ± 0.7	4.68 ± 0.04	4.76 ± 0.07	0.88 ± 0.03	1.21 ± 0.03	3.09 ± 0.06	4.21 ± 0.09
p-value[7]		NS	NS	NS	0.019	<0.001	<0.001	0.003	<0.001
WHtR (cm/m)									
< 50.0	732	117 ± 0.5	76 ± 0.4	4.59 ± 0.03	4.54 ± 0.04	0.69 ± 0.02	1.34 ± 0.01	2.83 ± 0.04	3.57 ± 0.05
≥ 50.0	257	129 ± 0.9	79 ± 0.7	4.64 ± 0.04	4.81 ± 0.07	0.88 ± 0.03	1.25 ± 0.02	3.09 ± 0.06	4.12 ± 0.08
p-value[3]		0.022	0.001	NS	<0.001	<0.001	<0.001	0.001	<0.001

[1] For BG the sample sizes are: N = 79, N = 408, N = 210, and N = 30 respectively for the BMI categories; N = 527 and N = 200 for the WC categories; N = 508 and N = 219 for the WHpR categories; N = 532 and N = 195 for the WHtR categories. [2] Standard error of the mean. [3] F-statistic from ANCOVA including age, sex, tobacco use, and the year of examination as covariates. [4] Not significant. [5] Male-specific cut-off value. [6] Female-specific cut-off value. [7] F-statistic from ANCOVA including age, tobacco use, and the year of examination as coviariates.

Prediction of CVD risk factors using obesity indices

The linear regression analyses showed that BMI was the best obesity index predicting SBP and DBP in male students (Table 4). The percentage of the variance of these two measurements explained was <5%. WC was also a significant, though not powerful, determinant of SBP. WHtR could better predict most of the serum lipoproteins, explaining 6.2% of TC, 10.6% of TG, 4.2% of LDL-C and 7.3% of TC:HDL-C variance. WHpR was a significant determinant of HDL-C. The same analyses within the female sample showed also that BMI was the most important predictor of blood pressure, explaining 11.9% of the SBP and 8.4% of the DBP variance (Table 5). WHtR could better predict LDL-C levels, and WC was the most important determinant of TG, HDL-C and TC:HDL-C, predicting 7.9, 7.6 and 10% of their variance respectively. In both genders, none of the obesity indices could significantly predict BG levels.

Using the odds ratios for the prediction of the presence of CVD risk factors, subjects above the selected cut-offs had higher risk for high blood pressure and dyslipidaemia (Table 6). Men with WHtR ≥ 50 had the highest risk for elevated TC (OR 2.26) and LDL-C (OR 1.83). Those with WHpR ≥ 0.9 had significantly higher risk for TG ≥ 1.5 mmol/l (OR 2.51), HDL-C < 0.9 mmol/l (OR 2.03), and TC:HDL-C ≥ 4 (2.78). Women with WHtR ≥ 50 had the highest odds for high DBP (OR 2.33) and LDL-C (OR 2.60), and TC:HDL-C ≥ 4 (OR 5.30). The risk for low HDL-C was significantly higher in female students with WHpR ≥ 0.8. Nevertheless, the odds ratios among the obesity indices differed only slightly and their 95% confidence intervals overlapped.

Discussion

In our survey, a relatively high proportion of University of Crete medical students were overweight (25 ≤ BMI < 30 kg/m^2) or obese (BMI ≥ 30 kg/m^2) (27.6 and 4.3%, respectively). Although the range of definitions complicates comparisons with other studies of young adults or medical students, these percentages are among the highest reported in literature. A recent study in Slovakia showed that 16% of male but only 2% of female medical students had a BMI > 25.0 kg/m^2 [27]. In a study of male medical students in the US, nearly one-fifth of the subjects had a BMI > 24.7 kg/m^2 and a further 30% were classified as overweight with BMI 22.8–24.7 kg/m^2 [28]. Another survey at Louisiana State University during 1987–1992 showed that 37% of males and 9% of females were overweight [29]. Two percent of men but no women had BMI ≥ 30 kg/m^2. The self-reported prevalence of overweight among New Jersey medical students was 35.8% [30]. A study conducted among 154 medical students in South Africa reported rates of overweight and obesity that were

Table 4: Regression analysis of blood pressure, glucose, and lipoproteins on obesity indices in male students[1]

Dependant variable[2]	obesity indices	beta	adjusted R^2	t-statistic	p-value
SBP	BMI	0.266	0.048	3.3	0.001
	WC	0.485	0.025	3.6	<0.001
DBP	BMI	0.215	0.049	4.5	<0.001
BG	—	—	—	—	—
TC	WHtR	0.217	0.062	4.3	<0.001
TG	WHtR	0.263	0.106	5.5	<0.001
LDL-C	WHtR	0.180	0.042	3.4	0.001
HDL-C	WHpR	-0.255	0.045	-5.1	<0.001
TC:HDL-C	WHtR	0.244	0.073	4.7	<0.001

[1] N = 527 except for BG analysis where N = 412. [2] All four obesity indices, age, tobacco use and the year of examination were initially included in all regression models.

Table 5: Regression analysis of blood pressure, glucose, and lipoproteins on obesity indices in female students[1]

Dependant variable[2]	obesity indices	beta	adjusted R^2	t-statistic	p-value
SBP	BMI	0.346	0.119	6.6	<0.001
DBP	BMI	0.288	0.084	5.3	<0.001
BG	—	—	—	—	—
TC	—	—	—	—	—
TG	WC	0.285	0.079	5.5	<0.001
LDL-C	WHtR	0.161	0.023	3.0	0.003
HDL-C	WC	-0.270	0.076	-5.2	<0.001
TC:HDL-C	WC	0.312	0.100	6.1	<0.001

[1] N = 462 except for BG analysis where N = 346. [2] All four obesity indices, age, tobacco use and the year of examination were initially included in all regression models.

Table 6: Risk for the presence of hypertension and dyslipidaemia according to the obesity status

	Odds ratios (95% confidence interval)			
Men (n = 527)[1]	**BMI ≥ 30 kg/m²**	**WC ≥ 90 cm**	**WHpR ≥ 0.9**	**WHtR ≥ 50**
SBP ≥ 130 mmHg	1.81 (0.64–5.10)	1.24 (0.69–2.23)	1.62 (0.87–3.02)	1.37 (0.77–2.43)
DBP ≥ 85 mmHg	2.73 (1.13–6.59)[2]	1.38 (0.84–2.27)	1.11 (0.66–1.87)	1.46 (0.90–2.37)
TC ≥ 5.2 mmol/l	2.01 (0.80–5.05)	1.91 (1.18–3.10)[3]	1.70 (1.01–2.84)[2]	2.26 (1.40–3.67)[4]
TG ≥ 1.5 mmol/l	2.62 (0.80–8.64)	1.80 (0.83–3.92)	2.51 (1.11–5.69)[2]	1.72 (0.78–3.80)
LDL-C ≥ 3.4 mmol/l	1.46 (0.55–6.04)	1.67 (1.04–2.70)[2]	1.80 (1.09–2.98)[2]	1.83 (1.14–2.94)[2]
HDL-C < 0.9 mmol/l	2.39 (0.94–6.04)	1.61 (1.00–2.58)[2]	2.03 (1.23–3.35)[3]	1.34 (0.84–2.14)
TC:HDL-C ≥ 4	2.36 (0.86–6.47)	2.16 (1.38–3.39)[4]	2.78 (1.69–4.57)[4]	2.09 (1.35–3.26)[3]
Women (n = 462)[1]	**BMI ≥ 30 kg/m²**	**WC ≥ 80 cm**	**WHpR ≥ 0.8**	**WHtR ≥ 50**
SBP ≥ 130 mmHg	2.98 (0.34–26.12)	0.87 (0.17–4.33)	1.16 (0.27–4.98)	0.71 (0.09–6.00)
DBP ≥ 85 mmHg	3.15 (0.89–11.13)	1.77 (0.92–3.41)	1.26 (0.65–2.41)	2.33 (1.09–4.96)[2]
TC ≥ 5.2 mmol/l	1.34 (0.35–5.16)	1.49 (0.83–2.68)	0.98 (0.56–1.72)	1.53 (0.75–3.12)
TG ≥ 1.5 mmol/l	0.01 (0.00–1.53)	3.80 (0.51–28.13)	3.44 (0.57–20.67)	7.19 (0.95–54.49)
LDL-C ≥ 3.4 mmol/l	2.35 (0.66–8.42)	1.97 (1.12–3.47)[2]	1.32 (0.77–2.26)	2.60 (1.33–5.07)[3]
HDL-C < 0.9 mmol/l	2.77 (0.54–14.26)	1.98 (0.91–4.29)	3.33 (1.63–6.79)[4]	2.83 (1.19–6.73)[2]
TC:HDL-C ≥ 4	3.67 (0.99–13.67)	4.21 (2.35–7.55)[4]	3.71 (2.14–6.41)[4]	5.30 (2.66–10.58)[4]

[1] Logistic regression models including age, tobacco use, and the year of examination as independent variables. [2] $p < 0.05$, [3] $p < 0.01$, [4] $p < 0.001$

8.9% and 2.5% respectively for Indian and 19.7% and 4.6% for black students [25]. Overweight or obesity among black female medical and nursing students was found to be 30.6% [31].

Central obesity levels among medical students varied widely according to the anthropometric index used – a common problem found in similar surveys, as no consensus about the appropriateness of the different obesity indices or cut-off points has been reached [32,33]. We adopted the WC and WHpR cut-offs proposed by Dobbelsteyn *et al* [21] for Caucasian populations. With regard to WHtR, no established cut-offs exist to this point and our selection was based on the findings of Ko *et al* who provided evidence of WHtR ≥ 50 being the most appropriate cut-off for the risk of presence of CVD risk factors in both sexes [22]. Despite the differences in the observed obesity rates obtained using the different indices, it can be seen that a considerable proportion of medical students were characterized by central fat distribution, about 33.4% of men (this being the average percentage corresponding to WC ≥ 90 cm, WHpR ≥ 0.9 and WHtR ≥ 50.0) and 21.7% of women (the respective percentage in women using cut-offs of WC ≥ 80 cm, WHpR ≥ 0.8, WHtR ≥ 50.0).

A striking finding of our study was the high prevalence of major CVD risk factors, notably high blood pressure and adverse lipid profile, among University of Crete medical students. The rates of hypertension and dyslipidaemia reported here appear to be much higher than corresponding results of other surveys involving medical students. A study performed among black and Indian medical students in South Africa disclosed rates of high blood pressure (≥ 140/90 mmHg) of 2.5 and 4.2% respectively [25]. Hypercholesterolaemia (TC ≥ 5.2 mmo/l) and high LDL-C (≥ 3.9 mmol/l) was present in 19.4 and 16.9% respectively for Indian students, and 7.3 and 8.9% for black students. New Jersey medical students reported high DBP, SBP and TC levels at percentages of 4.2, 3.5 and 21.3% respectively [30]. A survey conducted among medical students at Louisiana State University between 1988 and 1992 reported rates of high SBP that were 4% for both men and women [29]. Eleven percent of women and 4% of men had DBP > 90 mmHg. The prevalence of high TC during 1991–92 was 18% for men and 31% for women [29]. Another study among University of California – San Diego medical students during 1986–1989 reported that 6.6% of them had LDL-C ≥ 150 mg/dL (3.9 mmol/l), 20% had TC > 200 mg/dL (5.2 mmol/l) and only 8.7% had high SBP or DBP [34]. A large cross-sectional survey among first-year medical students in the UK between 1948 and 1968 reported rates of elevated blood pressure that were somewhat higher than those in our study. The authors found that 29.9% of the males had high-normal blood pressure (≥ 130/85 and < 140/90 mmHg) and another 32.0% were hypertensive. The respective percentages for females were 21.8 and 16.9% [35].

Assessing the risk for the presence of major CVD risk factors in young adults is of particular importance, since it would allow us to promptly identify persons at high risk for development of clinical CVD later in life. In this context, obesity indices such as BMI, WC, WHpR and WHtR are all considered useful non-invasive anthropometric measurements to provide information on cardiovascular risks. The results of the univariate analysis showed that all four indices were related to higher levels of CVD risk factor variables except for glucose, where no significant associations were observed. One likely explanation for the glucose – obesity index relationships not reaching the 5% level of statistical significance is that our subjects were young adults aged 22 ± 2 years with relatively low BG levels (median 4.6 mmol/l [84 mg/dl] with only 10 subjects having BG ≥ 6.1 mmol/l), compared to the ranges found in older adults [36,37]. Another explanation is that as the glucose measurements were available only for a sub-sample of the students. Although the sub-sample with BG measurements was random, any statistical inferences have the inherent limitations of analyses involving sub-samples. Nevertheless, and with regard to other CVD risk factor variables, our findings are in agreement with several studies performed on large cross-sectional samples [21,38] but also young adult groups [39,40]. There is lack of consistency, however, in the selection of the most useful anthropometric indicators for prediction of CVD risk factors [32], particularly for young adult populations.

In our sample of medical students, aged 20–40 years, both linear and logistic regression analyses disclosed that BMI was a better predictor of elevated blood pressure. Similar results have been reported elsewhere [41,42] and evidence suggests that central obesity indices (such as WC) contribute only slightly to be predictive value of BMI [43]. Our results couple also with those of the Bogalusa Heart Study, where none of the WC, WHpR or WHtR measurements predicted the blood pressure levels of young adults in multivariate models [44]. Nonetheless, there are many studies with different conclusions [21,22,45].

Central obesity indices were mostly correlated with adverse serum lipids and lipoproteins. Several studies conclude that WC might be a superior index predicting the presence of central adiposity and dyslipidaemia [21,46,47]. We found that WC was a strong indicator for abnormal lipid profile within the female sample of medical students, whereas WHtR could better identify men with dyslipidaemia. The latter finding has also been reported by Ko *et al*, although their study involved Hong Kong Chinese adults aged 37 ± 9 years [22]. In both genders, the obesity indices could only explain between 2.3%

and 11.9% of the variance of the CVD risk factor variables. These low percentages are probably a result of the multi-factorial nature of these CVD risk factors.

Conclusions

The main findings of this study are summarized as follows: a) a substantial proportion of young Greek medical students were overweight or obese, b) obese students had higher levels of major CVD risk factor variables, namely blood pressure, serum lipids and lipoproteins, and c) BMI was found to be a useful index for the prediction of high blood pressure; WC in women and WHtR in men were also strong indicators for abnormal serum lipids and lipoproteins.

Our results highlight the necessity to institute effective prevention and health promotion programs in Greece targeting at young age groups. In view of the fact that medical students are not representative of the general population, studies should be extended to the Greek adult population and investigate the presence of obesity and major CVD risk factors and their trends over time.

Competing interests

None declared.

Authors' contributions

GB performed physical measurements, collected data, and drafted the manuscript. IM performed physical measurements, collected data, and reviewed the manuscript. ML carried out the statistical analysis and participated in data collection. AK conceived of the study and participated in its design, and also performed physical measurements. All authors read and approved the final manuscript.

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